

that among the Hopi Indians there are priests skilled in the lore of the sun, who determine, by observation of the points on the horizon where the sun rises or sets, the time of the year proper for their religious observances. An important ceremony is performed at the winter solstice, and in December 1897 Dr. Fewkes made a special journey to Arizona to study the ritual on the spot. This is not the place to refer to the ethnological aspects of the ceremonials witnessed by him, but the following extract from the Report of the U.S. Bureau of Ethnology will interest students of primitive astronomy.

"We are justified in accepting the theory that sun and moon worship is usual among primitive men. Whether that of the sun or of our satellite was the earlier, it is not in the province of this article to discuss, but it is doubtless true that sun worship is a very ancient cult among most primitive peoples. The Pueblos are not exceptions, and while we cannot say that their adoration is limited to the sun, it forms an essential element of their ritual, while their anhydrous environment has led them into a rain-cloud worship and other complexities. I think we can safely say, however, that the germ of their astronomy sprang from observations of the sun; and while yet in a most primitive condition they noticed the fact that this celestial body did not always rise or set at the same points on the horizon. The connection between these facts and the seasons of the year must have been noted early in their history and have led to orientation, which plays such an important part in all their rituals. Thus the approach of the sun to a more vertical position in the sky in summer and its recession in winter led to the association of time when the earth yielded them their crops with its approach, and the time when the earth was barren with its recession. These epochs were noticed, however, not by the position of the sun at midday, but at risings and settings, or the horizon points. The two great epochs, summer and winter, were, it is believed, connected with solstitial amplitudes, and the equinoctial, horizontal points, unconnected with important times to agriculturists, were not considered as of much worth. There is every evidence, however, that the time of day was early indicated by the altitude of the sun, although the connection of the altitude at midday with the time of year was subordinated to observations on the horizon."

STELLAR RADIATIONS.—Referring again to the problem of the measurement of stellar radiations, mentioned in our issue of May 12 (p. 39), the recent improvement in galvanometers ought to help the matter towards solution. At the meeting of the Physical Society on May 13, Prof. Ayrton said that the sensitiveness of these instruments had increased during the last few years in the ratio of 27 to 3,310,000. Of course it must be remembered that these figures apply to a particular class of instrument, and that they are based upon a somewhat empirical definition of the factor of sensitiveness. Nevertheless, they do indicate advance in the refinements of current-measurement.

It is to be hoped that similar attention may now be given to perfecting an electrometer for extremely small potential-differences; such an instrument is required for the development of photo-electricity generally. The sensitive plates of the cells used by Prof. Minchin for stellar measurement are only a few square millimetres in area; the advantage of this is that several of them can be placed together at the focus of a telescope. Their function is, not to give current, but potential differences when exposed to light. They respond chiefly to yellow radiations, and each plate, irrespective of its size, gives from one-third to one-half a volt, for daylight. If electrometers could be improved in the ratio 27 to 3,310,000, the experiments made by Pouillet, just fifty years ago, might be extended almost to the circumjovial planets.

THE LATE PROF. SOUILLART.—At the meeting of the Paris Academy of Sciences on May 23, M. Callandreau gave a short account of the late Prof. Souillart, whose death we have already announced. Prof. Souillart was elected a Correspondant of the Academy in succession to M. Gylden, the Academy thus showing its esteem for the astronomer who during thirty years devoted his leisure to the study of the theory of the satellites of Jupiter, and succeeded in bringing out important complements of the chief work of Laplace. It was while studying under M. Puiseux, at the Normal School, that M. Souillart had his inclination turned to celestial mechanics. In 1865 his "*Essai sur la théorie analytique des satellites de Jupiter*" appeared in the *Annales* of the School, and formed the basis of two later memoirs

—one, published by the Royal Astronomical Society, devoted to the analytical theory of the movements of the satellites; while the other, dealing with the reduction of the formulæ to numbers, appeared in the thirtieth volume of the "*Mémoires des Savants étrangers*." In addition to these publications, a series of notes appeared in the tenth, eleventh, and twelfth volumes of the *Bulletin astronomique*. The whole of these works formed the basis of the treatment of the satellites of Jupiter given by M. Tisserand in his "*Traité de Mécanique céleste*."

When M. Souillart left the Normal School he was appointed professor of mathematics in the Saint-Omer High School, and at the same time was attached to the Faculty of Sciences at Nancy. In 1873 he became professor of mécanique rationnelle at Lille University, and, some years later, professor of astronomy, which post he occupied at the time of his death.

THE INDUSTRIAL APPLICATIONS OF ELECTRO-CHEMISTRY.

THAT electricity is able to bring about chemical change appears to have been observed for the first time about the middle of last century. With Volta's discovery of the principle of his pile, in 1792, it became possible to set larger quantities of electricity in motion, and in 1800, the year in which Volta described his first large battery, the study of the chemical effects of the electric current may be said to have commenced with the observations of Nicholson and Carlisle on the electrolysis of water. They were the first to notice the separate evolution of the products of the decomposition at opposite poles; so that our knowledge of electrolysis, upon which the majority of the applications of electro-chemistry depend, may be said to have been acquired in the nineteenth century.

In the early 'thirties it was repeatedly proposed to deposit metals by immersing the object to be coated in a solution of the metal, placing it in contact with a more oxidisable metal. An external source of current was applied to electrotyping in 1839 by Jakobi, Spencer and Jordan independently of each other: the first-named also describes the employment of electrolytic gas in producing lime-light. The use of a current generated by magneto-electric machines was patented in 1842, and, according to Mr. Swan, current generated in this way was employed by Messrs. Elkington at Birmingham in that year. It was not, however, until 1864-5 that the more perfect machines of Pacinotti and Wilde made it possible to produce the electric current at a sufficiently economical rate to permit of its employment in a chemical process on the manufacturing scale. The electrolytic refining of copper was patented by Mr. J. Elkington in 1865 and 1869, and in the latter year the first electrolytic copper refinery was erected at Pembrey, near Swansea. The progress of electro-chemical industry was at first slow, but the improvements in dynamos and steam-engines, stimulated by the rapid extension of the applications of electricity to lighting and other purposes, the development of water powers, and last, but not least, the impetus given to the study of electro-chemistry by the theories of Van 't Hoff and Arrhenius, have contributed to make this progress during the past decade extraordinarily rapid. A circumstance, the effect of which on the future development of the applications of electro-chemistry is not to be underrated, is the evolution of a new type of chemist—one, namely, who adds to his knowledge of chemistry a competent knowledge of physics and especially of electricity; there can be no doubt that the country in which the facilities for obtaining training of this kind are defective will be heavily handicapped in the future. With special electro-chemical laboratories being founded at almost every university and polytechnic in Germany, it is depressing to see so little being done in our own country (more especially since it is apparently becoming increasingly difficult for foreigners to obtain admission to the German laboratories).

The present position of technical electro-chemistry has not been attained without many failures; instructive and interesting as many of these are, it is impossible to refer to them within the limits of this article, which must, therefore be confined to a general description of processes actually employed.

The oldest and most important of these is the electrolytic copper-refining process. The copper containing 0.3 to 2 per cent., or sometimes more, impurity is cast into plates which are suspended, some 3 or 4 inches apart, in large, lead-lined wooden boxes. Between each pair of plates a thin sheet of pure copper is suspended, and the solution, containing 15 to 20 per

cent. of crystallised copper sulphate and 5 to 6 per cent. of sulphuric acid, run in. The impure copper plates, of course, form the soluble anodes, the thin sheets receiving the deposit of pure copper. A current of from 100 to 200 amperes per square metre is usually employed, the E.M.F. being 0.2 to 0.4 volt. The electrical energy needed is, therefore, 0.1 to 0.2 electrical horse-power hour per pound of copper deposited. Considerable variations in the details of working are found in different works, owing to the varying local conditions. When a larger current density is employed the amount of electric energy required to deposit a pound of copper is greater, but, on the other hand, the copper is deposited more quickly, and therefore, for a given output, less copper is locked up in the baths, less labour is required, and a smaller plant is sufficient. In order to obtain a homogeneous deposit of copper the solution must be kept in circulation, otherwise a deficiency of copper near the cathode surface would arise, which would lead to the formation of a non-coherent impure deposit. Of the impurities in the anodes, gold, silver, and part of the arsenic and antimony remain undissolved, whilst iron, nickel, and the remainder of the arsenic and antimony pass into solution. The two latter metals are deposited along with the copper if they are allowed to accumulate too largely in the solution, especially if the amount of free acid present is small. The solutions must therefore be purified from time to time, and this forms the main difficulty of the process. By blowing air through the solution, after neutralising it with cupric oxide, ferric arsenate and basic antimony sulphate are deposited; but large quantities of copper sulphate are thus accumulated, which are difficult to dispose of. Where cheap power is available, the impure solutions may be electrolysed with insoluble anodes of lead and the copper, arsenic and antimony deposited; otherwise evaporation and recrystallisation must be resorted to.

The anode slimes which contain Au, Ag, Se, Te, Bi, Sb, and As, are worked up to recover the precious metals. In 1896, 137,000 tons of electrolytic copper were obtained, of which the United States produced more than all other countries together. The greater part of this pure copper is employed for electrical purposes, where its high conductivity is of paramount importance. The electrolytic copper is obtained in a coarsely crystalline condition, and is fused before use. Mr. Elmore aims at depositing the copper directly in the form in which it is to be employed; copper tubes, for example, are made by depositing the metal upon a rotating cylinder, the surface of the deposit being constantly polished by a prismatic piece of agate which moves backwards and forwards parallel to the axis of the cylinder. This produces a very dense and tough deposit, and at the same time permits of the employment of a current density as high as 600 amperes per square metre. The removal of the cylinder from the tube is very simple when it is made of some easily fusible alloy.

The electrolytic process for making aluminium has entirely superseded the chemical process, the superiority of the former (from a commercial point of view) being demonstrated by the diminution in the price of aluminium from over 20s. per lb. in 1888 to about 1s. 4d. to-day. The electrolyte employed is a solution of alumina in a fused mixture of the fluorides of aluminium and of the alkali or earth-alkali metals. Minet has used a mixture of common salt and aluminium fluoride, but it would appear that the solvent usually employed is cryolite from which iron and silicon have been removed by a preliminary electrolysis. The baths consist of large iron, carbon-lined boxes, the lining forming the cathode. The anode consists of massive blocks of carbon suspended above the bath, and dipping under the fused electrolyte almost to the bottom of the bath. The electrolyte is maintained in the fused state by the heat generated by the passage of the current, and the aluminium collecting on the bottom of the bath is run off from time to time. The alumina alone undergoes decomposition, the oxygen combining with the carbon anode and escaping as carbonic anhydride. Anhydrous alumina is shovelled on to the surface of the bath as required, and serves to protect the fused mass below from loss of heat by radiation. Although attempts have been made to refine aluminium containing iron and silicon, they do not appear to have met with success, and it is therefore necessary to exclude these impurities from the materials used. The pure alumina used in the process is prepared from bauxite. A current of 7000 amperes is passed through each bath (the current density being probably about 2.5 amperes per sq. cm. of cathode), an E.M.F. of about 5 volts being required. The current efficiency

is considerably less than the theoretical amount, owing to some secondary action, so that from 14 to 18 electrical horse-power hours are required to produce a pound of metal. The annual production of aluminium is rapidly increasing, and is at present considerably over 2000 tons. Notwithstanding the very large consumption of electrical energy in this manufacture, it is interesting to note that the cost of the pure alumina is the largest individual item in the total cost of production.

The problem of utilising aluminium presents as great difficulties as that of its economical production. Mr. A. E. Hunt, of the Pittsburgh Reduction Company, has recently given an interesting account of the applications of aluminium, from which it appears that these difficulties are being overcome.

The energetic reducing action of aluminium is utilised in many ways, the most important being the production of steel castings; two to five ounces of aluminium per ton suffices to remove oxygen from the steel, and so to obviate to a great extent the formation of blow-holes in the castings. A little aluminium added from time to time to the baths of molten zinc used in galvanising, removes the oxide and keeps the baths fluid. The addition of a little aluminium in making brass castings increases their soundness and strength in a similar way.

Aluminium is also used instead of brass for a multitude of small cast and stamped objects which do not require to be soldered; there would still appear to be no trustworthy method of permanently soldering aluminium. Aluminium may possibly be used as a conductor of electricity, though at present the advantage in price lies with copper; the specific conductivity of aluminium is 63 to 64 per cent. of that of copper, whilst copper is 3.3 times as heavy.

The history of the electro-metallurgy of zinc is mainly a record of failures. Zinc is readily deposited from neutral or slightly acid aqueous solutions or from the fused chloride, but, from the former, is very prone to separate in a spongy form. Mylius and Fromm show that this is probably due to the formation of traces of oxide, and is prevented by the presence of reducing agents. Vigorous circulation of the solution is also advantageous. The presence of metals more electro-negative than zinc, which deposit on it and promote its oxidation, also produces the spongy deposit. The difficulty of insuring the absence of such metals from solutions obtained from zinc ores, as well as the low price of the metal, which precludes any elaborate purification, probably account for the slow progress of this industry. Progress is, however, being made. Dieffenbach's process is in successful operation at Duisberg in Germany. In this a solution of zinc chloride, obtained by leaching a zinciferous iron pyrites after submitting it to chlorinating roasting, is electrolysed; but further details are wanting.

The Ashcroft process obtains coherent zinc by employing a somewhat basic solution of zinc sulphate or chloride in the cathode compartments of the electrolytic cells, whilst the Siemens and Halske process employs somewhat acid zinc sulphate solution. Both these processes are at work on the large scale, but their ultimate success does not seem to be yet quite assured; so that a more lengthy description may be dispensed with.

At Tarnowitz an alloy of zinc and silver with a little lead and copper, obtained by desilverising lead with zinc containing about 0.5 per cent. of aluminium, was refined electrolytically, using a slightly basic concentrated solution of zinc and magnesium chlorides as electrolyte, and rotating zinc plates as cathode. The insoluble anode mud thus obtained contained about 75 per cent. of silver, and the zinc deposited was almost chemically pure.

Electro-galvanising is also now somewhat largely employed, the electrolyte being a solution of zinc sulphate. Here again close attention to the current density and composition of the solutions is required to secure a smooth and adherent deposit.

Nickel.—Whilst it is perfectly easy to deposit a very thin film of nickel by electrolysis, the metal peels off if a thicker deposit is attempted. According to Foerster, however, tough, homogeneous plates of nickel of any thickness may be deposited from aqueous solutions of the sulphate or chloride if they are heated to from 50° to 90° C. The nickel obtained is, however, not so pure as is the case with copper, cobalt and iron being found in the refined metal in about the same quantities present in the unrefined. Electrolytic nickel is now a commercial article, part of it being obtained from alloys of copper and nickel containing a considerable amount of sulphur, which are used as anodes, the copper being first deposited, whilst the nickel goes into solution, from which it is subsequently deposited.

The electrolytic removal of tin from tin-plate is said to be carried on to a considerable extent. The tinned scrap is suspended in iron baskets which form the anode, and the tin deposited in the spongy form on sheet-iron kathodes, the electrolyte being a solution containing 12 to 15 per cent. of sodium chloride, to which a little caustic soda is added from time to time to prevent the precipitation of stannous oxide. The solution is warmed to 40° or 50° C., and since tin dissolves under these circumstances independently of the electric current, it is necessary occasionally to evaporate the solution and work up the residue for sodium stannate. Sodium is now made exclusively by the electrolysis of fused caustic soda. In Mr. Castner's process the heat generated by the passage of the current is utilised to keep the bath in the fused state. Magnesium is also a product of electrolysis. The small quantity produced is made at Hemelingen, near Bremen, by the electrolysis of perfectly dry, fused carnalite (magnesium potassium chloride). The iron crucible in which the salt is melted serves as kathode, the central carbon anode being surrounded by a perforated porcelain or stoneware cylinder which retains the chlorine.

The application of electrolysis to the precipitation of gold from cyanide liquors, marks an advance of some importance in the metallurgy of gold. Gold is not completely precipitated in a reasonable time by zinc from solutions containing less than 0.1 or 0.2 per cent. of free potassium cyanide, whereas with the electrolytic process the concentration of the solution is a matter of indifference. It thus becomes possible, by the employment of very dilute cyanide solutions, to extract economically the small quantities of gold contained in slimes and tailings which would otherwise have been thrown away. A further advantage of the electrolytic precipitation is that the gold obtained contains some 89 per cent. of gold, instead of the 70 per cent. contained in the zinc bullion. The solutions to be electrolysed contain from 0.01 to 0.05 per cent. of potassium cyanide, according to the nature of the ore treated, together with from 1 to 4 dwts. of gold per ton of solution, in the form of potassium aurocyanide. They have, therefore, a very high resistance. Owing to the very small quantity of gold to be deposited, however, a very small current is sufficient (0.6 ampere per square metre), and the baths can be worked with the moderate E.M.F. of 4 volts. The quantity of electric energy required is thus small, and its cost is almost negligible compared with that of the rest of the process. The solution flows into the electrolytic tank at one end, and passes alternately over and under the electrodes until it flows out of the tank deprived of 80 to 90 per cent. of its gold. The kathodes consist of thin sheets of lead, and the anodes of iron enclosed in canvas bags to retain the precipitate of prussian blue which forms on them. They are placed about 1½ inches apart. The gold remaining in the liquors flowing from the electrolytic tanks is not lost, these liquors being made up to strength with fresh cyanide and used again. After remaining in the tanks some months the lead kathodes are sufficiently rich in gold to be removed and submitted to cupellation. Owing to the important advantages already mentioned, the employment of this process is rapidly extending; in 1896, two years after the first installation of the process, over 46,000 ounces of gold were obtained in the Transvaal by means of it, and at present it is much more extensively used.

Turning, now, to the application of electrolysis to the production of substances other than metals, there is an important group of industries engaged in the electrolysis of potassium and sodium chlorides, producing, according to the conditions employed, caustic alkalis and chlorine, hypochlorites or chlorates.

In the first case it is necessary to keep the primary products of the decomposition separate, and this is accomplished in two ways: (1) by the use of a porous diaphragm; (2) by means of mercury. The manufacture of a diaphragm which shall be sufficiently durable with a solution of caustic soda on one side of it, and of chlorine on the other, is by no means easy. The fact that diaphragms are being successfully used proves, however, that the difficulties are not insuperable. A more serious drawback is the impossibility of separating the caustic alkali from the chloride. As soon as the solution at the kathode contains hydroxyl ions, these begin to migrate, under the influence of the current, toward the anode, in time passing into the anode compartment and giving rise to the formation of hypochlorites and chlorates and to the evolution of oxygen, and so diminishing the efficiency of the cell. It is therefore necessary to draw off the solution from the kathode compartment of the cell while it

still contains much undecomposed chloride, and to separate this from the caustic alkali as far as possible during the process of concentration.

The process of Hargreaves and Bird avoids this to a great extent in a very ingenious way. The kathode in this process consists of a sheet of copper gauze, upon which the diaphragm is built up of asbestos mixed with some cementing material. The diaphragm, with the copper gauze outside, forms the outer wall of the cell which contains the solution of salt and the carbon anode. The caustic soda is thus formed outside the cell, and is washed down and converted into carbonate by a mixture of steam and carbon dioxide. The diaphragm is made so impervious that, when in good condition, no liquid will run out of the cell, and only three molecules of salt to 100 molecules of sodium carbonate are obtained. The diaphragms last about thirty days, but, according to Kershaw, yield less favourable results toward the end of the time. Hulin's process is somewhat similar to that of Hargreaves and Bird, the diaphragm-kathode consisting of a sheet of porous carbon through which the caustic soda solution is forced as quickly as it is formed by hydrostatic pressure inside the cell.

When mercury is employed as the kathode, the diaphragm becomes unnecessary, the mercury taking up sodium in contact with the salt solution and giving it up to pure water in another vessel. A great many devices have been contrived for causing the mercury to alternately perform these functions. The simplest and most effective is undoubtedly the rocking cell of Mr. Castner. This consists of a shallow oblong tank divided into three compartments by means of partitions which do not quite reach the bottom. A thin layer of mercury lying on the bottom of the cell lutes the spaces below the partitions, thus dividing the cell into three separate compartments. The two end ones contain strong brine and carbon anodes, the central one pure water and an iron kathode which is connected electrically with the mercury. The cell is tilted slightly from side to side, so that the mercury flows from one end compartment to the other, always covering the floor of the central compartment, however. In this way the sodium taken up at the ends is conveyed to the water in the centre. The central compartment forms really a galvanic element, consisting of sodium amalgam and iron in a solution of caustic soda; the connection of the iron to the mercury short circuits this cell, and therefore hastens the dissolution of the sodium. The caustic soda obtained in this way is practically pure, and the current efficiency over 90 per cent. of the theoretical value; whilst the electromotive force required is 4 volts for each cell.

If instead of keeping the products of the electrolysis of a salt solution separate they are mixed together in the cold, a solution of hypochlorite is formed. A limit to the concentration attainable is, however, quickly reached, partly owing to the electrolysis of the hypochlorite, partly to its reduction by the hydrogen evolved. Hermite employs rotating zinc kathodes, between each pair of which a platinum gauze anode is fixed, the electrolyte, consisting of a solution of salt and magnesium chloride, flows through the apparatus, yielding a weak bleaching liquor suitable for bleaching paper pulp or for deodorising sewage, in which latter case sea water may be used. Kellner attains the same result by using a long tank in which a large number of carbon plates are fixed in such a way that the solution flowing in at one end of the tank must circulate between each pair of plates before passing out of it. Only the two end plates are attached to the terminals of the dynamo, so that each intermediate plate acts on one side as anode, on the other as kathode.

The electrolytic preparation of potassium chlorate was patented by Charles Watt as early as 1851, but the idea was not put into practice until 1889, when Gall and Montlaur started the first electrolytic potassium chlorate plant at Villers-sur-Hermes in Switzerland. They employ thin platinum-iridium anodes and iron kathodes, and maintain the solution at a temperature of 50° to 60° C. by the heat evolved by the passage of the current. The electrolytic cell is divided by a diaphragm of porous earthenware into a smaller kathode, and a larger anode compartment, in order to prevent as far as possible the reduction of the chlorate by the hydrogen evolved at the kathode. A current of 10 amperes per sq. decm., and an E.M.F. of 5 volts are used, and the caustic potash formed at the kathode transferred to the anode compartment sufficiently fast to absorb all the chlorine evolved. The potassium chlorate crystallises out in the anode compartment, its solubility being diminished by the employment of a saturated solution of potassium chloride as electrolyte. The

diaphragm may be dispensed with, according to Oettel, if the solution is alkaline, because in that case potassium chlorate is not reduced, to any appreciable extent, by nascent hydrogen. High current density at the kathode, and low current density at the anode, promote the formation of chlorate, the best results being obtained when a quantity of oxygen is evolved, corresponding to some 30 or 40 per cent. of the current passed. The current efficiency is reported to be from 65 to 70 per cent., and there is no doubt that the electrolytic process will eventually displace the older chemical one, about one half of the world's consumption of chlorates being already supplied by it.

Of other electrolytic processes there is not very much to be said.

In Mr. A. B. Brown's process for the manufacture of whitelead a 10 per cent. solution of sodium nitrate is electrolysed in order to obtain caustic soda and nitric acid, which are subsequently used for the preparation of lead nitrate and its precipitation as lead hydroxide, the latter being finally converted into lead carbonate by means of a solution of sodium bicarbonate.

Applications of electrolysis to tanning and to the purification of sugar have been frequently proposed, but nothing very definite is known as to their success.

Among organic compounds iodoform has long been prepared by the electrolysis of an alkaline solution of potassium iodide containing alcohol. According to Elbs and Hertz good results are obtained by electrolyzing a solution containing 5 to 6 grams of sodium carbonate, 10 grams of potassium iodide and 20 cc. of alcohol in 100 cc. of water at a temperature of 60° C. with a current density not exceeding 1 ampere per square decimetre. Under these circumstances the current efficiency is over 97 per cent. and the iodoform produced perfectly pure.

It has been proposed to apply ozone to a great variety of purposes, but here again a lack of trustworthy information about the results is found. According to Mr. Swan, however, it is used in making vanilin and heliotropin. When used as a bleaching agent it is necessary to use it in conjunction with other substances, such as hypochlorites or hydrogen peroxide. Mr. Andreoli has devised an ozone producer in which the electrodes are furnished with numerous points and separated by a glass plate. In order to prevent the heating of the gas it is caused to pass rapidly through the apparatus, and the electrodes are made hollow and cooled by internal circulation of water. The silent discharge is obtained by means of an alternating current dynamo and high tension transformer yielding a rapidly alternating current at a pressure of 10,000 volts or more. By this means 30, or under favourable conditions 40 grams of ozone are obtained for a horse-power hour.

Electro-thermal Processes.—The electric current possesses two considerable advantages as a heating agent; in the first place temperatures otherwise unattainable may be reached by its aid, and secondly the heat may be applied directly and economically to the substances which are to be caused to react. The three most important products of the electric furnace are carborundum, phosphorus, and calcium carbide.

Carborundum, a compound of carbon and silicon in equal atomic proportions, was prepared by Acheson in 1891, in the course of experiments on the artificial production of the diamond. It is remarkable for its extreme hardness, which is only inferior to that of the diamond. It is prepared by heating a mixture of powdered coke and sand, to which a little sawdust and salt are added in order to make the mass more porous, in a furnace 16 feet long, 5 feet wide and 5 feet deep, which is built up of loose fire-bricks. Through the end walls of the furnace bundles of 60 carbon rods, each 3 inches in diameter pass, which are connected inside the furnace by a cylindrical core of small pieces of coke. This core is surrounded on all sides by the mixture of sand and coke. The passage of the current through the core gives rise to a cascade of small arcs between the pieces of coke, which soon raises the whole core to a very high temperature which is communicated to the surrounding charge. A current of 6000 amperes at 125 volts pressure is passed for 36 hours, after which the furnace is allowed to cool and the hollow cylinder of crystalline carborundum surrounding the core removed. About 5·3 electrical horse-power hours are expended in producing a pound of the crystalline product, a considerable quantity of valueless, amorphous carbide of silicon being also formed at a greater distance from the core, where the temperature is lower. The carborundum is obtained in the form of steel grey to brownish green crystals, the coloration being due to iron; it is a valuable abrasive, cutting the hardest steel without destroying its temper; and is being largely used in place of emery. The production

has increased from 15,000 pounds in 1893, when it was first made on a manufacturing scale, to about one and a half million pounds in 1897.

The manufacture of phosphorus in the electric furnace has been carried on for some years by means of the process of Readmann and Parker and Robinson. Wöhler found, as long ago as 1830, that phosphorus may be obtained from calcium phosphate by heating it to a high temperature with sand and carbon, calcium silicate and carbon monoxide being produced. The employment of the electric furnace has made it possible to use this process for the manufacture of phosphorus. Naturally occurring phosphates are used and siliceous material added, which will furnish a readily fusible slag. The finely-powdered mixture of these substances with carbon is fed in through a hopper at the top of a brick-lined trough, 18 inches square and 36 inches deep, through opposite sides of which the carbon electrodes are introduced. The fused slag collects at the bottom of the furnace, whence it is run off from time to time in the same way as in a blast furnace, whilst the mixture of phosphorus vapour and carbonic oxide pass to the condensing apparatus through an opening placed near the top of the furnace. More than 80 per cent. of the phosphorus contained in the materials used is obtained, the loss being largely due to the presence of iron which combines with phosphorus to form a phosphide which remains in the slag. The heat is concentrated mainly between the electrodes, so that the walls of the furnace do not suffer.

Calcium carbide was prepared by electrically heating together carbon and lime, in 1892 by Moissan in France, and by Willson in America; its manufacture is now carried out on a very considerable scale, both in America and in Europe. The production is said to be about 20,000 tons yearly. The furnaces employed vary considerably in details of construction and in magnitude. Those employed at Niagara consist of a square brickwork shaft in which a bundle of carbon rods, which forms one electrode, is suspended. The bottom of the shaft is closed by an iron rectangular box, running on rails, the bottom of which has a thick lining of carbon, which serves as the other electrode. The finely-powdered mixture of coke and lime is fed into the space round the upper electrode through channels in the brickwork sides of the shaft. The arc having been established between the electrodes, the mixture of coke and lime is shaken down into it, and converted into calcium carbide, which remains in a semi-fluid condition upon the lower carbon plate. The calcium carbide, being a fairly good conductor of electricity, now serves as the lower electrode, fresh material being constantly added to its upper surface until the iron box is full, when it is run out and a fresh one substituted for it. The current employed is 1700 to 2000 amperes, and the electromotive force 100 volts, a pound of the carbide being obtained for an expenditure of 2·25 electrical horse-power hours. When sufficient carbon is employed in the mixture, the electrodes are very little acted upon; the excess of carbon which is required depends very much on the kind of apparatus employed. A pound of well-made carbide yields 5 cubic feet of acetylene gas, the employment of which for lighting appears to be making some progress.

In concluding this brief sketch of the applications of electrochemistry, it is perhaps worth pointing out that, important and interesting as are the applications which have been made, those which yet remain are still more so. For example, it is possible, by compressing sulphur dioxide and air into separate carbon tubes dipping in dilute sulphuric acid, to cause the two gases to combine to form sulphuric acid, and at the same time furnish an electric current. The alluring prospect of obtaining electric energy as a bye-product in a chemical works, should be a sufficient incentive to efforts to overcome the numerous difficulties in the way.

THOS. EWAN.

THE STRANGLING OF AN ELEPHANT.

ONE of the elephants in Barnum and Bailey's Show, which has been visiting Liverpool during the past two weeks, having recently shown signs of insubordination, Mr. Bailey determined, in order to perfectly safeguard his visitors, to sacrifice the animal. He has had during his life occasion to destroy many elephants, which, as a rule, he has handed over to experienced veterinary and other surgeons, who have tried various methods, such as poisoning, shooting and bleeding. All have proved, however, unsatisfactory, because uncertain, tedious, and not seldom dangerous to those engaged in conduct-